ALUMINUM-COPPER-NICKEL ALLOY AS A POSSIBLE SUBSTITUTE FOR ALPHA BRASS FOR USE IN CARTRIDGE CASES

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CARNEGIE INSTITUTE OF TECHNOLOGY

COLLEGE OF ENGINEERING

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

SUBJECT "Aluminum-Copper-Nickel Alloy as a Possible Substitute for Alpha Brass for Use in Cartridge Cases."

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I Introduction.

1. The present tendency toward reduction of armaments in general and reduction in size of men-of-war in particular keeps the Navy Department constantly on the lookout for improvements which will cause an increase in battle-worthiness of the vessels it is allowed. In former times the general policy was to first decide on armor. armament, and speed of the vessel and then design a hull capable of carrying the load. At the present time, with tonnages limited by treaty, the problem is exactly reversed. The size of the hull is fixed and then armor, armament, and speed balanced to fit. Consequently, any reduction in dead weight is highly desirable, and the outstanding opportunity for effecting this reduction is to substitute light metal alloys for the heavier metals and alloys in as many places as possible.

2 Certain types of Naval vessels employ fixed ammunition¹ exclusively while others employ it in certain groups of their guns. These using fixed ammunition exclusively are the smaller vessels where a saving in weight of dead load means a material increase in battle-worthiness. As a further consideration, however, the reduction in weight of the unit charge is important when it is realized that with even the most modern mechanized loading apparatus the charge is manually handled at one or more points in the

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The present work was undertaken with the hope of determining a light alloy which might be suitable for use in cartridge cases. A rough estimate places the possible reduction in weight of the unit charge at 15-30 percent.

3. In adapting a light alloy to such use many difficulties are encountered. The alloy must have the following properties: (1) low specific gravity; (2) melting point and thermal conductivity sufficiently high to enable it to withstand elevated temperatures for short intervals of time; (3) strength and hardness to enable it to withstand accidental knocks in handling and prevent its extrusion into the extractor recess during firing; (4) sufficient elasticity to cause it to spring at the instant of firing and allow the gun to take the load, subsequently returning to its initial form when the pressure is released; (5) ductility to allow deep drawing during manufacture. Physical properties of an alloy as usually determined will give only a good indication of how that alloy will act in a particular application. The present instance is not an exception to this statement and it is admittedly true that in this case they will give only a general indication. The only worthwhile test must be the actual use of the alloy for the particular purpose.

Light alloys have been tried for this purpose with no apparent success as yet.² That work is being continued with the assistance of the Aluminum Company of America's Engineer Sales Department but it is confined to adaptations of the standard commercial alloys. In the second se

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Light allogs have been tried for bids purpose with an apparent conners as yet. This and is helds continued with the assistations of the Aberland Conjung of Lowerton's Multiman Delay for articles but it is another to should be should be standard symposothed alloys. 4. From an inspection of the literature ^{3,4,5,6,7} the conclusion was reached that a suitable light alloy might be found in the Aluminum-Copper-Nickel system. It was previously known that alloys 25⁹ and 515¹⁰ had been tried. The alloy 25 (commercially pure aluminum) gave fair results but was far from a success due to its softness. The alloy 515 as used was practically a total failure. From this it might be considered that the melting point of the 25 was sufficiently high, and the melting point of the 515 was sufficiently low, due to alloying additions, to prevent or allow intergranular melting. A permissible assumption is that a light Aluminum-Copper-Nickel alloy with a melting point near that of the 25 and strength and hardness superior to that of the aluminum might be successful.

5. The alloys to be investigated were basically the 96Al-4Cu alloy with $\frac{1}{2}$, 1, 2, and 4% nickel substituted for an equivalent amount of aluminum. The general plan of work consisted of

(1) Determining Liquidus and solidus for each alloy.

(2) Determining effect of nickel content by

(a) Microstructure study

(b) Hardness tests

(3) Determining physical properties with various heat treatments.

6. It is desired at this point to make the following acknowledgements:

(1) To Commander W.E.Brown, U.S.Navy, for his initial suggestion and subsequent help. 4. Yrom an iingertian of the literature 2.4.2.4.7 had enamination was remned that - unitable light aloy aight to found in the thermost that - unitable light along the stonely moves there alogs 95° and 218¹² and been tries. The alley 26 (domenter-14) gave along these, The alley that was far from a metropes due to its softness, The alley dis ar used the precisely a bount fallers. From the it aught he constances the the malitur point of the 50 m antifactor right, and the malitur point of the 50 m interpretation along a start the sectors, the 50 m interpretation of the malitur point of the 50 m interpretation is a start to the sectors, to prevent or alog interpretation of the sectors into the second interpretation of the sectors into a start interpretation of the sectors of the sectors interpretation of the sectors of the sectors interpretation of the sectors into a start in the interpretation of the sectors and the sectors in the of the is and strength and terms into the the interpretation of the sectors and the sectors in the of the is and strength and terms in the the interpretation of the sectors and strength in the interpretation of the measure of the sectors of the interpretation of the measure of the sectors of the interpretation of the measure of the sectors of the sectors.

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B) Bernstein teste

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(2) To Mr. E. H. Dix, Jr. of the Aluminum Company of America and his staff for furnishing the alloys and subsequent assistance and advice in the metallographic work and in making the tensile specimens.

(3) To Mr. G. P. Halliwell of the Carnegie Institute of Technology faculty for his advice and assistance.

II. Material, Apparatus, and Methods

7. The analyses of the four alloys used are shown in Plate 1. They were prepared and analyzed at the Research Laboratory, Aluminum Company of America, New Kensington, Pa. The base metal was the high purity grade of aluminum known as grade 7A.

8. A small nichrome-wound resistance furnace was used for the study of effects of heat treatment. Temperature control was entirely by hand. The temperatures were determined by a noble-metal thermocouple which was calibrated against a secondary standard of known accuracy. The potentiometers used were (1) a Leeds and Northrup Type K for the solidus and liquidus determinations and (2) a Leeds and Northrup portable type, calibrated against the Type K, for temperature control of the furnace. A "drop-bottom" fer the furnace was built which would permit a quenching interval of approximately 1/5 second. The temperature differences within the furnace at 600°C. at the level of the platform were 4°C. from side to center, 4°C. to a distance of 1-2" above the platform. (c) The max for the Plane Service the Windows Owngoing is converse and here a watt for foreign disc wile/a and subscripted assistance and wirth in the boundle confide were and the setup the boundle spectment.

(0) To Mr. G. T. Ballioull of the Garagite Institute of Fourierous families for Dis Africa and marinfamore.

II. SAMETAL AUGERSIAN AND POINTERS - INCOME.

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(1) Using carbon crucibles and with the thermocouples immersed in the metal and protected from it by a silica tubecooling and heating curves were taken on each of the four alloys to determine their solidus and liquidus temperatures. At least two curves were taken on heating or cooling each alloy and in most cases three or more. The results, as tabulated in Plate 2, are believed to be accurate within $5^{\circ}C$.

(2) After determining the solidus and liquidus temperatures samples $\frac{1}{2}$ "x $\frac{1}{2}$

(3) One group of specimens was then maintained at 618° C. for $\frac{1}{2}$ hour and quenched. Upon polishing and etching with the 1% HF it was seen that incipient melting had commenced. This is shown in Plate 7 for alloy #2. Similar conditions were noted in the other three.

(4) Hardnesses (Rockwell B) were taken immediately upon quenching in an effort to determine the advent of any precipi-

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111 VALUE DEFEND DEDITIES AND WITH THE THERESONGLOU immersed in the metal and protected from it by a milter take sociling and heating durres were balan on such at the four alloys to determine their solides and liquidue succerebures. At ionat two morees more taken on besting or cooling and miley and in and toget throw a norm. The results, an takeleted in cists 3, are believed to to sequrate within 5%.

(3) ifted determining the molidum and liquidus temperatures amongles $[*n]^* al/b^*$ of mash alloy verse out. Taking them in groups of four (one of each alloy) they were placed in the furmers, which had been tigged with the drop-botton, and siven the rollowing much tracted to a temperature of 300°C, and minimized at that temperature $(\frac{1}{2}, 300, 1, 400)$ is being rollowing the 247°C, to 540°C, and after holding a temperatures ranging from 247°C, to 540°C, and after holding act this temperature $\frac{1}{2}$ near the equations were quanched. The accuracity of this fast summing the equations were quanched. The appearance were then pollated and stated with 15 W (see all as in this temperature $\frac{1}{2}$ near transities to the state of the state of the temperature of the state of the state of the state of the act the temperature of the state of the state of the state of a to the temperature of the state of the state of the state of a to the temperature of the state of the state of the state of the temperature of the state of the state of the state of the act the state of the state of the state of the state of the act the state of the state of the state of the state of the act of the temperature of the state of the state of the state of the act of the temperature of the state of the state of the state of the act of the state of the act of the state of th

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(4) Hardnesses (Homewell 'S) were taken Lourdintely upon questing in an effort to behavelow from dreams of any presipttation. The results are plotted in Plate 8.

(.) A group of specimens were quenched after soaking for $\frac{1}{2}$ hour at 590°C. and then aged at various temperatures ranging from 100°C. to 450°C. for an additional $\frac{1}{2}$ hour. The aging at 100°C. was done in boiling water and at the higher temperatures in the nichrome-wound furnace. They were air cooled from the aging temperatures. Hardness (Rockwell E, 1/8" ball, 100 kg. load, B scale) was taken after aging and the results plotted as shown in Plate 9.

(6) The #1 and #4 half-inch plates were then tolled down, first hot and then finished with a 50% cold reduction. the final thickness was 0.064° (14 gage, A.W.G.). Flat tensile coupons were then punched and milled. A series of the test pieces were heat-treated as in (5) and physical properties determined for the two alloys in the cold-rolled and heat-treated conditions. At least two specimens were tested for each alloy and heat-treatment. The average results are plotted in plates 10-12 inclusive.

(7) The microstructure of alloys #1 and #4 after quenching and aging at 100° C. is shown in plates 13 and 14.

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tation. The reading are disted in Plate A.

(1) A group of specifiums were manoical ofter souling for [] at a 590°C. and them aged as marious temperatures remained from 100°C. to 450°C. for an edditional [hour. The astau at 100°C. was done in bailing water and at and higher bespectatores in the atom one in bailing water and at and higher souled from the adding temperatures. Therefore all 1/8° bails 100 kg. load, B scale) was taken ofter aging and the remains picked at above in 71ste 9.

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(6) The #2 and #4 balfwinds plates muto these bolied. down first hat and they distand with = 5% sold redection. the start interaction as 0.064 (15 gags A.*.).) I'll tenmits develow were then purched and milled. A series of the test places were hous-tracted as in (b) and physical pre-setion determined for the two alloys in the sold-relied and best-tracted word bout-tracted as in (b) and physical pre-sebest-tracted word there is a logs in the sold-relied and the set slop and bout-tractedes to operimone wave teached pre-set alloy and bout-tractedes (in another sold and the set alloy and bout-tractedes). The another and he was plotted in lates 10-12 inclusive.

(?) The alerbetruchure of alloys (1 and 24 after quandhing and seting at 160°C. is shown in plates 10 and 14

III Data and Results 10. Index of Plates Plate 1. Chemical Analysis of Alloys Solidus and Liquidus Temperatures 2. Microstructure Alloy #1, as quenched from 590°C. 3. 4. --#2 -88 ---#3 * 5. ---10 #4 " 25 ---- (1) 6. #2 618°C. 7. 28 報 -11 44 8. Hardness vs. Quenching Temperatures, all alloys, hot-rolled 9. Hardness vs. Aging Temperatures, all alloys hotrolled 10. Physical Properties vs. Heat Treatment, #1 alloy # ¥8. " " . 24 " 11. 12. Tensile Strength and Elongation vs. Heat Treatment, #1 and #4 alloys Microstructure #1 alloy cold-rolled, quenched and 13. aged at 100°C. 14. Microstructure #4 alloy, cold-rokled, quenched and aged at 100°C.

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				PLATE 1	
Alloy	si	Fe	Cu	Ni	(dift.)
#/	.04	. 01	4.20	.56	95.19
#2	.02	. 01	4.16	1.10	94.71
*3	.03	.02	4.00	2.00	93.95
#4	.03	.03	4.04	4.05	91.85

ANALYSES OF ALLOYS

				PL	ATE Q
Alloy		#1	#2	#3	#4
Liquidus	Heating	648	646	637	635
	Cooling	645	641	640	636
Solidus	Heating	620	620	625	618
	Cooling	617	620	620	617
			_	120	tindo

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LIQUIDUS AND SOLIDUS DETERMINATIONS





Alloy #1

Quenched from 590⁰C. Unetched X500



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Alloy #2

Quenched from 590°C. Unetched X500



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Alloy #3

Quenched from 590°C. Unetched X500

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Quenched from 590⁰C. Unetched X500





Alloy #2

Quenched from 618°C. 1% HF etch X500




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Alloy #1

Quenched from 590^oC. Aged at 100^oC. 1% HF etch X100





Alloy #4

Quenched from 590°C. Aged at 100°C. 1% HF etch X100

1 900

These ones internets then the back IV. Discussion of Results and Conclusions

11. The hardness tests of the alloys in the condition as quenched from various temperatures (see Plate 8) show nothing that can be called conclusive evidence of precipitation. It will be noted that while the hardnesses of the lower nickel alloys are consistently higher than those for the higher nickel alloys the values are practically constant over the range of quenching temperatures. The 1/16" ball (Rockwell B) is too small for this soft material but was considered satisfactory inasmuch as the results are purely relative and all hardnesses were nearly equal. The values obtained are all less than zero (Rockwell B) but assurance was obtained during the testing that the load was applied only through the ball.

In the composition range examined, the liquidus temperature decreases from 645°C. for the low-nickel alley to 635°C. for the higher-nickel alloy (Pinte 2). The solidus temperature is practically the same for the four alloys. While the rates of heating and cooling used were slightly high (4°C. per minute) the agreement between the heating and cooling temperatures indicates that any lag developed was not of serious consequence. The solidus temperature is the more important of the two because of the fact that with a rising temperature any intergranular melting will begin at that point. In the blast within the gun this would allow grains to be hlown loose from the main mass of metal. If this intergranular melting is not begun it is believed that the metal, even though reduced in strength due to the elevated temperature, will have IV. Discussion of Deamlys and Constones

11. The tendence tests of the alloys in the non-Altics as meaned from various temperatures (as when 3) show withing their can be emiled consinuing estimates of predictivities. It will be outed that wills the bardonaus of the lower maxed align are constructed in the these for the bigher states alloys the values are protione for the bigher state of queuestic fidnes are protion 1/14* test (becaused 3) is too mult for the solutions anterial big web considered activities the resonance web conditions are parents (be too mult for the solution of the maximum of alloys and all hardeneous web and the solution are parents (becaused 2) is too mult for the solution of all is allowed activities and all hardeneous web and condition are parent thread at all the defining temperatures and all is a second the obtained are all the bardeneous web and the solution are parent for the solution and the test of a solution are the solution and all the test the solution and all all all and all the solution the test of all all all all all the solution the test of the low and all all the solution the test of the test of all all all all all the solution the test of the test of all all all all the solution the test of the test of the test of all all all all all the solution the test of the test of the test of the test of all all all all the solution the test of test o

sufficient strength to withstand the blast. Solidus temperature will also depend on amounts of impurities present. It was for this reason that the so-called high purity grade 7A was chosen as the basic metal rather than the ordinary "commercially pure aluminum." In the 51S alloy there is an excess of sil.con which invites reference to the statement of Archer in Edwards. Frary, and Jeffries book that the solidue in Aluminum-Magnesium-Silicon alloys having Si in excess of the MagSi ratio occurs at approximately 550°C. with the freezing of the ternary eutectic. The final solidification probably takes place at a still lower temperature in 51S due to the presence of impurities. A comparison of the solidus temperatures of the subject alloys with those of the alloys 2S and 51S shows

Alloy	25	Al-Cu-Ni	515
Solidus temperature	658°C.	620°C.	550°C.

Thus, solidus temperature and with it resistance to intergranular melting for the Aluminum-Copper-Nickel alloys is seen to compare favorable with the 2S as against the 51S alloy.

The study of the microstructure revealed that the four alloys fall into two groups; the first group being the two low-nickel alloys and the second group being the two highernickel alloys. It was noted that over the whole range of temperatures from which quenched the alloys consisted of a ground mass of solid solution with scattered inclusions loautriciant strangth to adderses the blast. Soldar tess persited at an depend on marane of imperities promet. It as for this resour that he so-sailed bith perity grobs "A we drown as the basis acket ration from the collars "compression of adderse black antion from the collars as assess of addiced which invites reference to the antiment of Arbier is observe. To the 515 bills that he for an income the black and defined from the antistand and the black of the invites reference to the antiment of the state of the barries from the state back and another is observe. The second to the antithe solidar to the black on an and for the state in an another the black on the state of the second in the second of the black on an and for the second in a state of the black on an and the second of the solidition is fit due to the presence of inpurities. A nonparison of the state probably takes place of the second parison of the state of the presence of the second of the solidar test of the second of the state of the the solidar test of the second of the state of the the solidar test of the second of the second of the parison of the tight and the presence of the solid test with the solidar test of the second of the second of the solid of the solidar of the state of the second of the solidar allows the solid the solidar test of the second of the solid test and solid the solidar test of the solidar of the solid test allows the the solidar of the solidar of the solidar of the solid test allows with the solidar of the solidar of the solidar of the solidar allows with the solidar of the solidar of the solidar of the solidar allows and the solidar of the solidar of the solidar of the solidar allows with the solidar of the solidar of the solidar of the solidar allows

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The study of the midrosciructure revealed that the four alloys fail into the gradual the first group being the tee low-mickel alloys and the empeut draw being the tee biddernished alloys. It we which that over the whole range of sequeratory from which provided the alloys oreals to a stought and of solid boles to alloys another of a

cated largely at the grain boundaries. These inclusions were seen to increase with added nickel but at a faster rate.i.e., there are more than eight times as many inclusions in the 4% nickel alloy as in the alloy containing of nickel. In the first group the inclusions were wholly the ternary compound. T or Cu-Ni, as identified by the methods of Dix and Keith . In the second group there appears a greatly increased amount of the ternary compound together with a large amount of NiAl3. The presence of any GuAl, in any of the alloys at the as-quenched temperatures was not noted. While the short time of soaking is not sufficient to allow complete equilibrium to be reached the results obtained are believed to be qualitatively accurate. It is believed that this distribution effect is due to the normally strong attraction of nickel for copper. With small amounts of nickel present some of the copper combines with it and aluminum to form the ternary compound while the remainder goes into solution. With higher nickel content less of the copper goes to form solid solution and more forms the ternary compound until a point is reached where a large excess of nickel is needed to draw copper from solid solution in the aluminum. Nickel over and beyond this critical concentration would then unite with the aluminum and appear as NiAl. This is found to be the case for, with nickel over 1%, free NiAl is present. Both the ternary compound and the NiAl, appear as fairly large rounded particles, mestly at grain boundaries, and would be expected to have a negative effect on physical properties. This is corroborated by the physical data for the highermickel alloys.

sated largely at the grain boundary on. Trues includence vers soon to indvoice with added mickel wit at a farter returned. there are nore then width times as many inclusions in the st the same ball, the set is balled where the stokel sitor so in the sily containing of michol. In the tract drawn the inclusions years wholly the termin openiand. T or Quelly as fignitfied by the methods of Dis and Kalth . Inviews insurances without a proving a process while the of the ternary computed together with a large meansh of MLAL .. The persents of any Dudigin any of the elleys at the as-quenaled bedreakers and maked. While the shurt time of moniting is not smilldight to allow complete squilibris to be rowshed the results obtained and buildwoh to be qualitatively anoursts. It is believed that this distribution sifest in day to the movimily strive attruction of algorith the support. with maining of mining present some of the coppur dombines with it and aluminum to form the Sernery cancornil while the realizer gass into salution. With higher stovel dominat imam al the upper man to form sull solition and ners forms the Lorenty compound indil a point is reached where a large exercise of manned is meeted to draw equire fana solid and the two Line in the adjustment. Handle over and beyond this weithen consentration would than units with the alout and appear as Hill, . This is from in the line montherit for with adding and the free bill is pressed. How is to turnery composed and the HLAX, appake as fairly large remained participes, muching of grade burnharton, and would be showever to have a manified we wifer to physical properties. This is corrected by the pigerent ante fue bigered and show satel willows.

Nickel, therefore, having the power to take up and combine with all available copper to form the term ry compound as a rounded inclusion will act as a scavenger for the grain boundaries. While with proper treatment there is small likelihood of there being present any copper-aluminum eutectic, it is not an impossibility and the function of the nickel would be to draw this eutectic up into an inclusion much in the same manner that manganese is said to combine with sulphur in steel and form a rounded particle. This would remove the eutectic which might be present at grain boundaries and which, with its comparatively low melting point, 548° C., would allow early melting and disintegration.

It was originally intended to determine precisely the physical properties for the complete set of alloys with varying heat treatments. This phase of the work has had to be shortened, however, due to a lack of time. The heattreating of the tensile specimens was done in an electria resistance furnace with the specimens buried in sand in a sheet metal container and the temperature manually controlled to offset a large temperature gradient within the furnace and a poor automatic control. It was due to lack of a close automatic control that only comparatively short time of aging was used. All tensile properties were determined across the direction of rolling. The testing machine was a Tinius Olsen 50000-pound machine using a light poise to convert it to a 5000-pound maximum load. It was run at minimum speed. Yield points were determined by the drap of the beam and noting change in rate of application of lead.

To be noted on physical properties is the fact that

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combine with all realisits reaper to term the termery near possibles at a second distribution will out as a second or the gradic boundaries. While with proper incomment there to ann't likelihood of these being proper incomment the deper-mininum and the first of the of the second of the function of the subsector if is not as incomentative and the function of the sould be to firm the estimation of the an inclusion man is the same momen first manging as is and to contain with milenes in about and form a containt particle. This would remove the milestic which he proves for process of grain point helf". would allow early witting and distributions.

It was orighnally intraded to determine provisity bhe physical properties for the complete act of alloys with varying hast bredmanta. Tola phase of the work has bad to be alottened, however, due to a leave of blue. The masttranting of the reasing opecial and dama is a constant residence formed with the socilante buried in and in a sheet metal container and the bangerature monoxily controlled to differ a large theoremitation gradient while the formers and a poor mulaminity souther. It was don't that or a slow automatic control that only comparatively that time of arithe was wood. All tomatic properties ware datormined account the direction of rolling. The tarting making was a Winter Office Office Strong and the pattor a light pattor to never 12 the a fight same hour bar have by Pierrow of nicking openi. Theid maintee even determined to the date of the beam was matter stated in rate of application of inel.

To be noted an physical properties is the fact that

the material hot-rolled easily and on cold-rolling showed a clean smooth finish with no tearing. The final reduction in the cold state was fifty percent.

Just as the four alloys fall into two microstructure groups so do they fall into two groups in hardness values after heat treatment (Flate 9). The two alloys of higher nickel content are slightly softer than the two low-nickel alloys and do not respond an equal amount to heat treatment. This would be expected considering the larger number of inclusions present and consequently a smaller amount of dissolved copper with the higher nickel content, just as we would not expect a one-tenth carbon steel to be as heattreatable as one with higher carbon. It was assumed that other physical properties would likewise show a division and only the high and how nickel alloys were tested for physical properties. Plates 10 and 11 show the physical properties of the two alloys while Plate 12 shows a comparison of their tensile strength and elongations.

The solution heat treatment, i.e., quenching from near the solidus, followed by aging at 100⁰C., is considered to give the best combination of properties to these alloys.

Ni. content	T. S2 #/in2	Y. P. #/in2	Elong. 2"	R. A	nardness Rockwell E
言語	41200	29700	14	43	72
4%	32700	22700	19	37	57

It will be noted that the lower-nickel alloy is the stronger and harder of the two. the meterild 'not-rolies would be at an all-ralling answed a

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There as the four alloys fait into her alternativation aparts as a four the fait into her group is herdren when after and be the fait into her group is herdren when altern and a second single period from the new low-shoul state and is not requested something the integer and as a print in proceed something the intger and an a solved copper with the react second of the brought of a second and constants in and a second of the solved copper with the there alloys a soulid to be a the transation of any addition of the intger and a second integer and the react of the integer and a second of the solved of any addition into a state of the intger and and the second of the black defined and the intger and and and and the alloy and the middel state to be as the integer and the black and the middel state to be a state of the integer integer and the middel state to be a state of the integer and the middel state to be a state of the second is and the middel state and the definition properties. Firster to and its right is the first and and the integer is a state of the state of the integer and the state of the state of the base alloys which is the base the definition properties. Firster that is allow and a state of the state and of the sould be transfer and a state of the state of the state of the base alloys which is the base to be and the state of the base of the state of the is allow and a state of the state of the state of the base allows and is the state of the state of the state of the base of the state of the base of the state of the s

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12. The results comparable with those of Read and Greaves in their work on the physical properties of this system show good agreement. For the 92:4:4 Al-Cu-Ni. (nominal composition) alloys:

		Present York	Read and Greaves
Cold #	(Yield Point	30500	29600
Worked	Tensile Strength	36500	36800
	Elongation	3.3	3.8
	Reduction Area	27	6.2
	(Yield Point	5400	7200
Annealed	Tensile Strength	25400	25300
at 450°C.	Elongation	21	23.5
	Reduction Area	55	29.7

#Present work on sheet reduced cold about 50% in cross section to .064". Read and Greaves on 1" red cold drawn to 7/8".

It will be noted above that the greatest disagreement is confined to those properties, Yield Point and Reduction of Area, in which positive values are difficult to determine.

The alignment of the four alloys into two groups with the division at between one and two percent. nickel which was shown by the microscope and hardness tests agrees in general with the diagram of Bingham and Haughton.⁵ They place a phase boundary at between one and two percent. nickel. The liquidus temperatures also show good agreement. A marked disagreement is shown in the solidus 15. The results domparely with these of last of Sperce in their work on the physical properties of this organs, doe good agreement. For the 90:444 Al-Ja-37. (modual compasting) alloger

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the mentioned to be a programhing the granteet all angles and the mentioned to those programhing Yinde inter and induction of Arms in which postitive values are difficult to determine. The all-content of the four blicon balls and programits the division at became and and the personal, middel which was shown of the alongene and because there arouge the general with the disgram of Hadran and Touches for provide the place a phase boundary of between and and best provide. The along the includence to be and the second to along a phase boundary of between an and the along the second to the transformed between and the second to along a solution to be an and the second to be along the second of the transformed and the second to along the include the transformed along the second to along the second of the transformed and the second to along the second of the transformed and the second to along the second of the transformed and the second to along the second of the transformed along the second to along the second of the transformed along the second to along the second of the transformed along the second to along the second of the transformed along the second to along the second of the transformed to the second to the second to along the second of the transformed to the second to the second to along the second of the transformed to the second to the second to the second to along the second of the transformed to the second to the se

temperatures, however. In their determinations a great amount of difficulty was encountered in interpreting a number of minor halts in the cooling curves (inverse-rate). A close determination of solidus tem er ture under these circumstances is impossible but it is believed probable, as they state, that these minor halts were due to metastability in the liquid. On heating many of these retardations were not in evidence. In the present work solidus points were detyrmined on time-temperature rather than inverse-rate curves. The inverse-rate curve, while it does gove more definite determinations, also magnifies any experimental errors to a point where they may complicate the interpretations. The uniform results obtained in the present work lend assurance to the correctness of the determinations and the later work on heat treating, i.e., the solution heattre tment consisting of seaking at '90°C., shows positively that the solidus is above 585 C., the temperature determined by Bingham and Haughton. These variations may of course, be due to different amounts of impurities. No explanation is attempted for the still greater disagreement in solidus tem-

13. It is reiterated here that the only test which will give positive indication of the adaptability of this group of alloys to use in cartridge cases must be actual application. We can, however, make an estimate of this adaptability by examining the above data in the light of past experiment. The alloys designedly have a low specific gravity. The only advantage an alloy of higher nickel content might have over the low nickel alloy might be the presence of NiAl₃.

peratures for the low-nickel alloy.

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tempetering in strike. In their leteralisticas a grant amount af difficulty was anoquaterak in interpreting number of since builts in the sociling ourses (inverim-rate). A glose determinetion of solidar ten or three these as relations have in the out is in believed probables as thay state, that these miner halfs were don to mutambility to the Might. On Basting many of these retrictions much the evidence. In the present more relidua points area determined on time-tamperature rather than toversets surves. The incurserate ourse, will's it ices mys pare definite determinations, also manifies any agartmental strors to a point where they any compliants the interprethat income, Was modifies of the and the present work limd admirundo to the correctness of the determinations and the loter much on onch treating, ise-+ the solution hasts tractment uncelsting of making at 100°C .. shows yould'rain the anti-how an along and the the temperatury the test by Musica and succitant. There werlations sure of coorsers in the to different amounts of impurities. In amplanction in whitempark the she has been discovered in the second in the second in pursioned for the law-stelet aller.

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With what may be called an excess of nickel present, it is extremely unlikely that any copper could exist outside of either the solid selution or the ternary compound. It is believed possible; owever, that the small r amount of nickel, one-half ercent., is sufficient to spheroidize whatever free copper might be available as the ternary compound. Consequently. our consideration will devolve upon the low nickel alloy (951:4:1 AlcCu:Bi). It is composed initially to avoid the presence of any impurities which might allow earlier melting. When annealed at 450°C., its hardness, elongation, and reduction of area would indicate that it could be as easily drawn as the alloys 17S (duralumin) and 25S (silicon-manganese alloy), probably slightly more so. In the recommended heat-trated condition (quench at 590°C., aged at 100°C.) it has sufficient strength and hardness for all except rough usage. It has a solidus temperature comparable with that of the commercially pure aluminum, which, while not high, might be sufficiently elevated to prevent disintegration. At elevated temperature however, it is extremely soft and care must be taken when heat-treating not to strain it in any manner. Evidence of this softness occurred in attempting to heat-treat a specimen made up of laminations screwed together. The strain on the screw-head caused it to sink deeply into the outer metal when the metal was heated prior to quenching. Whether or not this softness will cause failure in the cartridge case during the firing is a subject for conjecture. Alloy 518 was not extruded into the extractor recess as much as alloy 25 and at the same time alloy 25 did not suffer from disintegration to

With whit may be emilted an element of night growthell. it is extremely unlikely that any negoer could extel outet of To initiani to line and this everyor " ordines, burnling adistance as designing af a fragment is appointing a - on viscous add as addactors of sight in the or and very on pound. Community- own constants will develop u.ch the Inw bister miley (Starts) AltGuild). It is empound infinity to avoid the pressure of any inquiribles which the midness, etampician, and redation of area would truitates that it could be an anoth divers he siles 192 (dereluein) and 355 [efilteon-menjanese slipy] - probably uttingly mare wo. In the recommended heat-try ted soughting (queened at DOO"C .. aged at 100"G.) it has sufficient ulreacts and hardness for all incess transf hands. It has a sighter the statute com rabie di the of the orestal it was alisedation of idals -dain son alide . with the authority Stavated to prevent Mainta making. It whimled temperature news means he dame your had the give the trans of it to the Some-transfers and to strain 15 to any many. Evidence of manifers a functioned of anitometic all investigated analities with and an effecte of residence surveys to strain on the man' incan three all the side of all into the base of the base of the the suish and booked print to gomentary. Netter in not this settaness will couse fulling in the saving and thering the firing is a value. for somissions, allor bid was not and In som to chile an door on devous telentrate and plat belings

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to the same extent that the 51S did. It might be expected that the Al-Cu-Ni alloy would resist disintegration equally as well as the 2S and that it would resist extrusion as well as the 51S.

The general conclusion is that a trial of this alloy in actual use would be worthwhile. It is not a conviction that it will be more adaptable than the standard commercial alloys but there is in its favon as against them. the difference in impurities and absence of alloying additions which might allow earlier melting.

14. A continuation of this work along the following lines would be advisable: (1) Testing of the chosen alloy by actual application (Commercial application of an alloy based on grade 7A aluminum would not be practical. But while it is desirable to have impurities a minimum, it is believed possible that use of a commercially practical high-purity grade of aluminum would give satisfactory results); (2) Determination of the physical properties of the two intermediate alloys of this group, noting any critical nickel content which would be expected at between one and two percent.; (3) Further determination of solidue temperatures working with alloys having varying amounts of impurities purposely added; (4) Further determinations of effects of heat-treatment involving a variation in time of aging, and quenching from temperatures below that used in the present work. to the same extant that the 018 dif. It might be exceeded that the AL-Ou-II alloy would restat distaining a comily as well as the IS and that it would restat accousts as well as the 315.

The general conclusion is that a trial of this shirt in actual use would be worthwhile. It is not a conviction that it will be more standard than the standard conversion alloys but there is is the forms as spalewit them, the difference in inputities and absence of alloying shittless when when when allow matiler mathing.

14. A continuation of this work ning the following times would be advisables (1) facting of the observe alog by sevent application (formergint applitubles of an alog thesed on rate 7A simulate mould not be precised. But while 15 is descrabe to have lagarities a statement to is boliered gravible block are of a commedially precised bid-paring draks of alusines would dive solicitostery remains) (1) inservices of this properties of the two interments) aligns of this properties of the two interments would be experied at bolieres on and the two interments accounts of the properties of the two interments beterminetion of while a bolieres on and the permanents (2) forther would be experied at bolieres on and the permanents (3) forther would be experied at bolieres on and the permanents of the second state of intermetion on and the permanents (4) forther would be the of a state of a permanent means involve determinetion of the offers of the permanent involves between the time of an and the state to alog a bolier would be appreciable of the offers of the permanent involves between the time of a state of a permanent involves the permanent involves and the bolier offers of the permanent involves the permanent involves and the state of a state of the permanent involves would be the offers of the properties of the permanent involves and the state of the permanent involves and the state of the permanent involves and the state of the permanent of the state of the permanent of the state of the permanent of the state of the permanent involves and the state of the permanent of the permanent involves and the state of the permanent of the state of the permanent of the perman

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V Appendix.

15. Helative References and Notes.

- 1 Note: Fixed amounition is the term applied to the charge for a gun where the propellant is contained in a cartridge case which is fixed to the projectile, the two constituting a unit mass; e.g., all pistol appunition is fixed amounition.
- 2 "Report on Conditions Developed in the Firing of Aluminum Cartridge Cases", Naval Gun Factory Report, 18 April, 1929, C.E.Margerum.
- 3 "Light Metals and Alloys, Aluminum, Magnesium", Circular of the Bureau of Standards, No. 346.
- 4 "The Properties of Some Aluminum-Mickel and Copper-Nickel-Aluminum Alloys", Read and Greaves, J.Inst.Met., 13, 100-159
- 5 "The Constitution of Some Alloys of Aluminum with Copper and Nickel", Bingham and Haughton, J.Inst.Net., 29,71
- 6 "The Aluminum Industry", Edwards, Frary, and Jeffries, Vol.2, Aluminum Products and Their Febrication.
- 7 "Metallurgy of Aluminum and Aluminum Alloys", R.J. Anderson.
- 8 "The Etching Characteristics of Constituents in Commercial Aluminum Alloys", Dix and Keith, Proc.A.S.T.M.<u>26</u>
- 9 25 Aluminum Co. of America contercially pure (99% +) aluminum, principal impurities iron, silicon, and copper.
- 10 518 Aluminum Co. of America alloy. Nominal composition: 1% silicon,0.6% magnesium, remainder aluminum plus impurities.
- 11 7A Aluminum Co. of America highest purity (99.95%) aluminum.

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- 2 Mater Mixed en anition is the test egalsized to the aberguties in gue where the grapelizat is contrained in a odriridge case mitch is fixed to the stopschie, iss ten constitution is unit asket; e.g., wil pistel examinition is fixed reconstibut.
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- "ILCHE Metels and Alloys, Aluminum, Secnesius", Circular of the Furshe of Standards, No. 546.
- "The Properties of Tome Association-Mickel and Supper-Street-Alsociation Alloys", had and breaves, J.Inst.Wet., 13, 100-109 "The Toxistitution of Some Alloys of Alsociation depose and Mickel", Plagham and Haughton, J.Inst. Not. 19, 71 "The Alsociate Industry", Noverda, Frary, and Istrico,
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Aluminum-copper-nickel alloy

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